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Izumi et al.

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(54) **METHOD IN A MOBILE TERMINAL FOR JUDGING A CONTACT BETWEEN AN OPERATING MEMBER AND TOUCHPAD**

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G06F 3/041 (2006.01)
(Continued)

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CPC ***G06F 3/01*** (2013.01); ***G06F 3/0418*** (2013.01); ***G06F 3/044*** (2013.01); ***H04M 1/0266*** (2013.01); ***G06F 3/0202*** (2013.01); ***G06F 3/04886*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 3/041; G06F 3/044; H03K 17/962
USPC 345/173–178; 455/566
See application file for complete search history.

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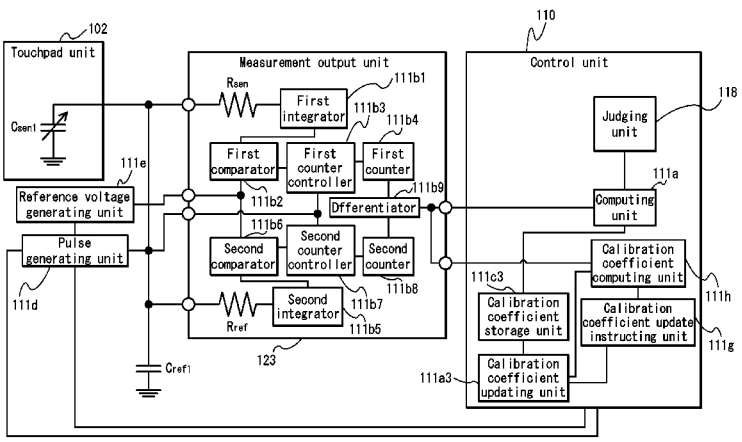
Primary Examiner — William Nealon
(74) *Attorney, Agent, or Firm* — Procopio, Cory, Hargreaves & Savitch LLP

(57) **ABSTRACT**

A mobile phone **100** having a capacitive touchpad unit **102** includes a touch sensor circuit **121** that outputs measurement values each indicating a capacitance of the touchpad unit **102**, a computing unit **111*a*** that computes a sensor output value based on each measurement output from the touch sensor circuit **121**, a calibration coefficient updating unit **111*a*3** that updates the sensor output value by updating a calibration coefficient so as to be equal to a predetermined reference value, a judging unit **118** that detects a contact based on the sensor output values, and a judgment threshold switching unit **133** that causes the judging unit **118** to use a provisional contact-judging unit for a time period starting when the update occurs during the time that the user's face is in contact with the touchpad unit **102** and ending when it is judged that the touch to the touchpad unit **102** is released.

11 Claims, 12 Drawing Sheets



(51) **Int. Cl.**

G06F 3/042	(2006.01)
G06F 3/01	(2006.01)
G06F 3/044	(2006.01)
H04M 1/02	(2006.01)
G06F 3/02	(2006.01)
G06F 3/0488	(2013.01)

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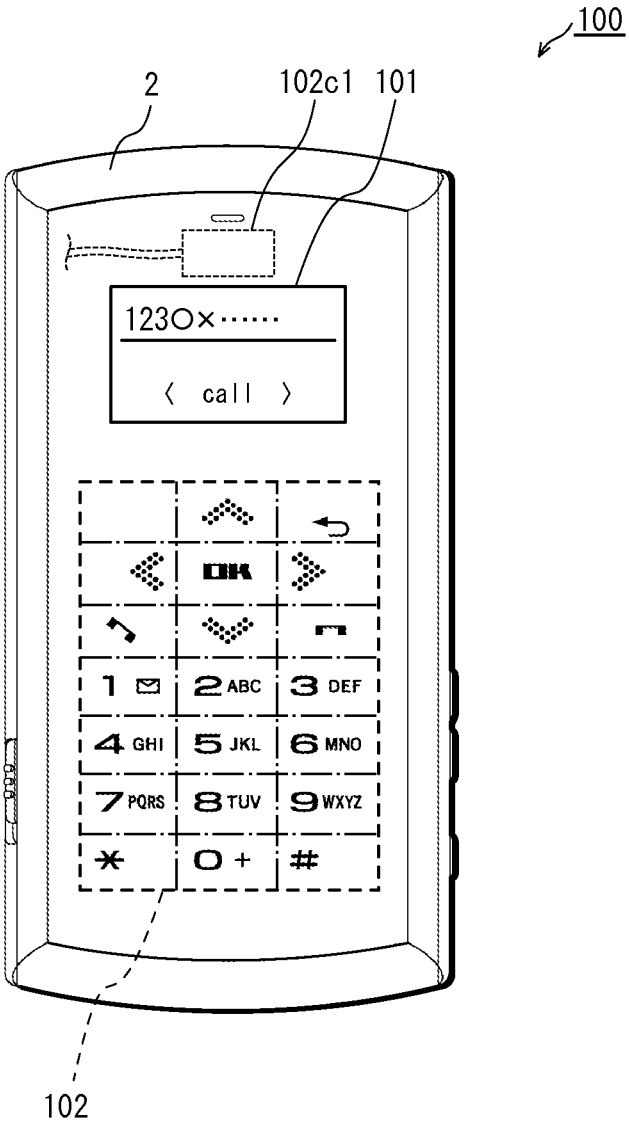
FIG. 1


100
2
102c1
101
123O×·····
〈 call 〉
OK
1
2 ABC
3 DEF
4 GHI
5 JKL
6 MNO
7 PQRS
8 TUV
9 WXYZ
*
0 +
#
102

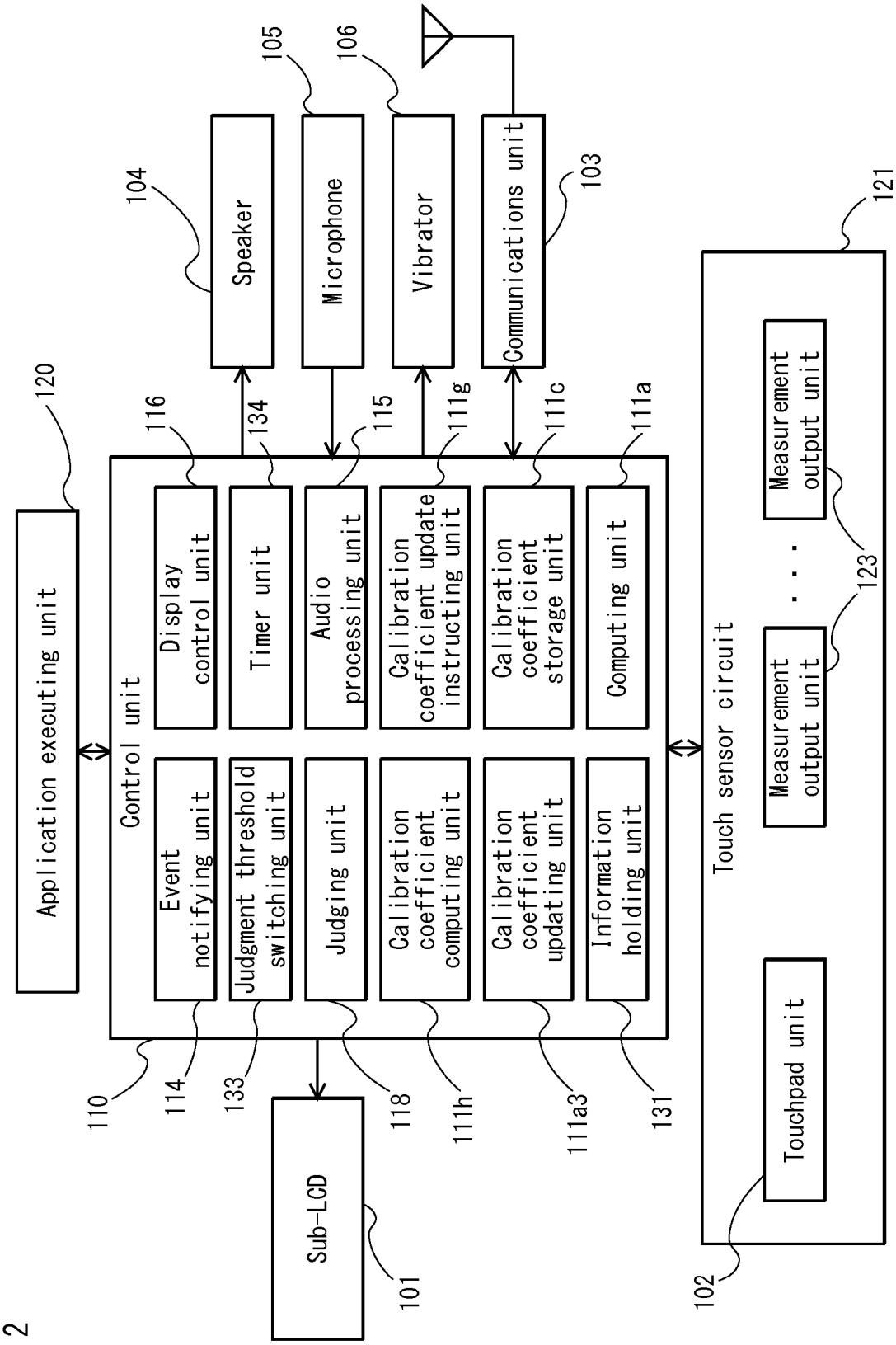

Application executing unit
120
Control unit
Event notifying unit
Judgment threshold switching unit
Judging unit
Calibration coefficient computing unit
Calibration coefficient updating unit
Information holding unit
Display control unit
Timer unit
Audio processing unit
Calibration coefficient update instructing unit
Calibration coefficient storage unit
Computing unit
110
114
133
118
111h
111a3
131
116
134
115
111g
111c
111a
Sub-LCD
101
Speaker
Microphone
Vibrator
Communications unit
104
105
106
103
Touch sensor circuit
121
Touchpad unit
Measurement output unit
Measurement output unit
123
102

FIG. 2

FIG. 3

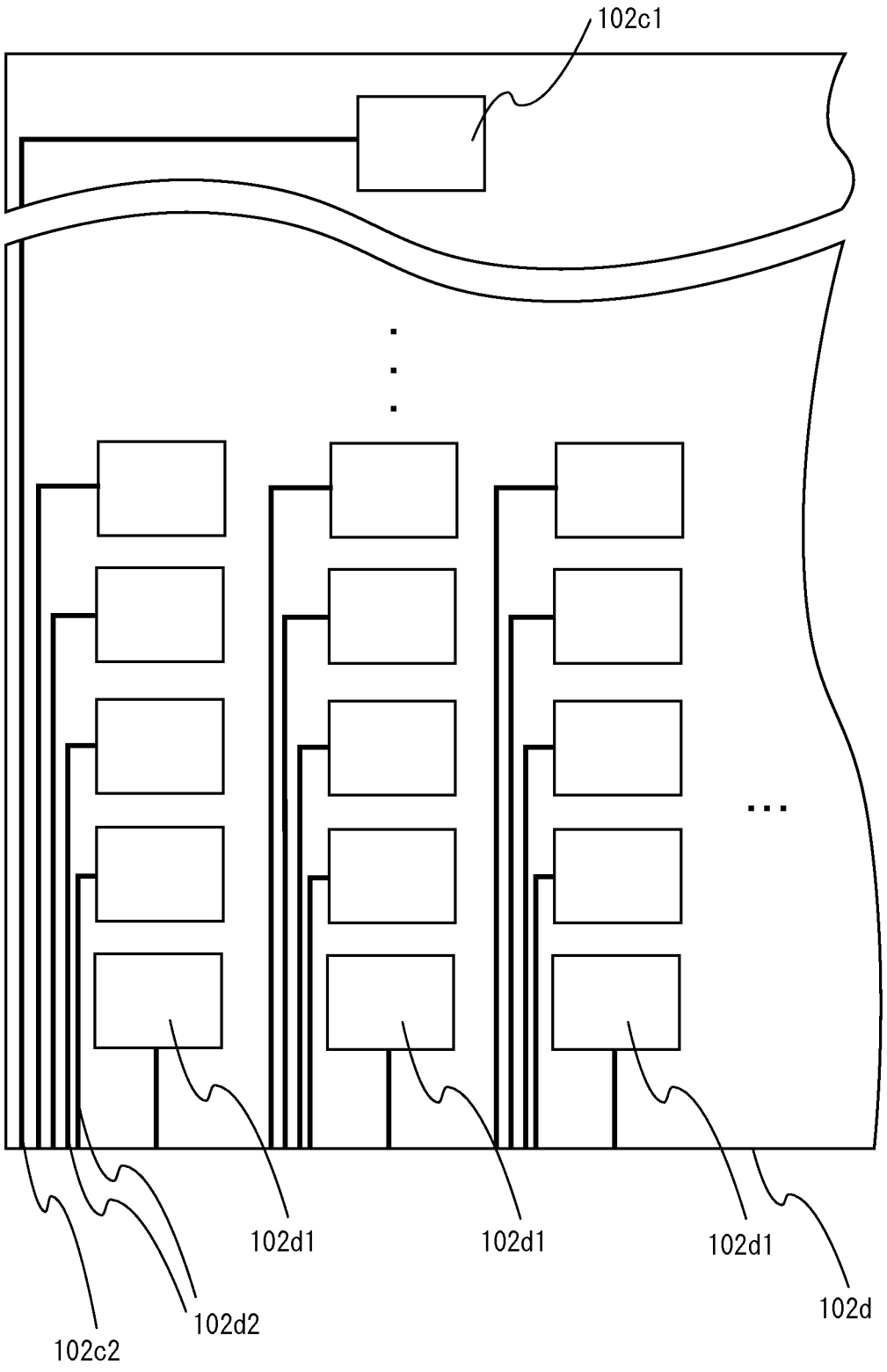


FIG. 4

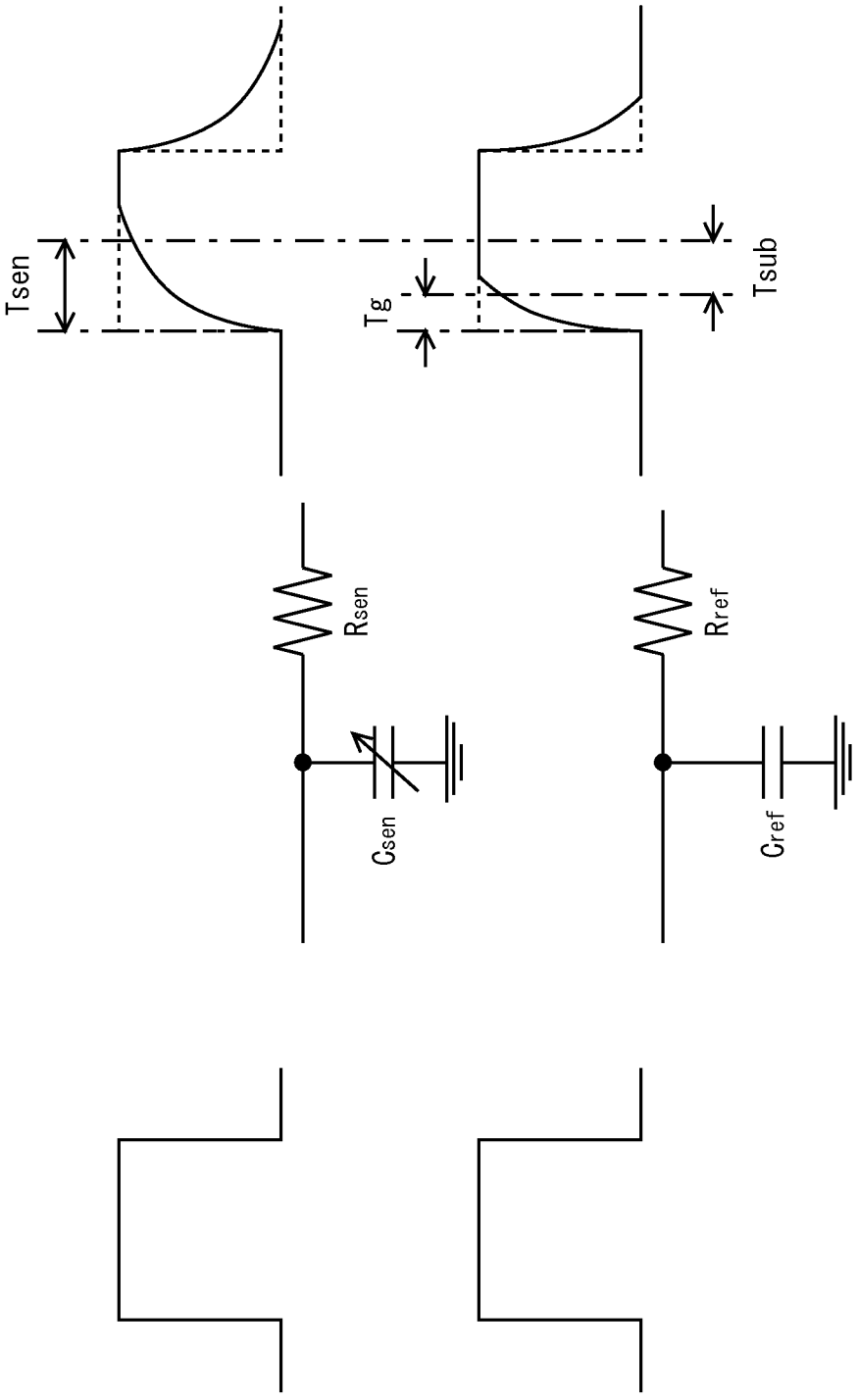


FIG. 5

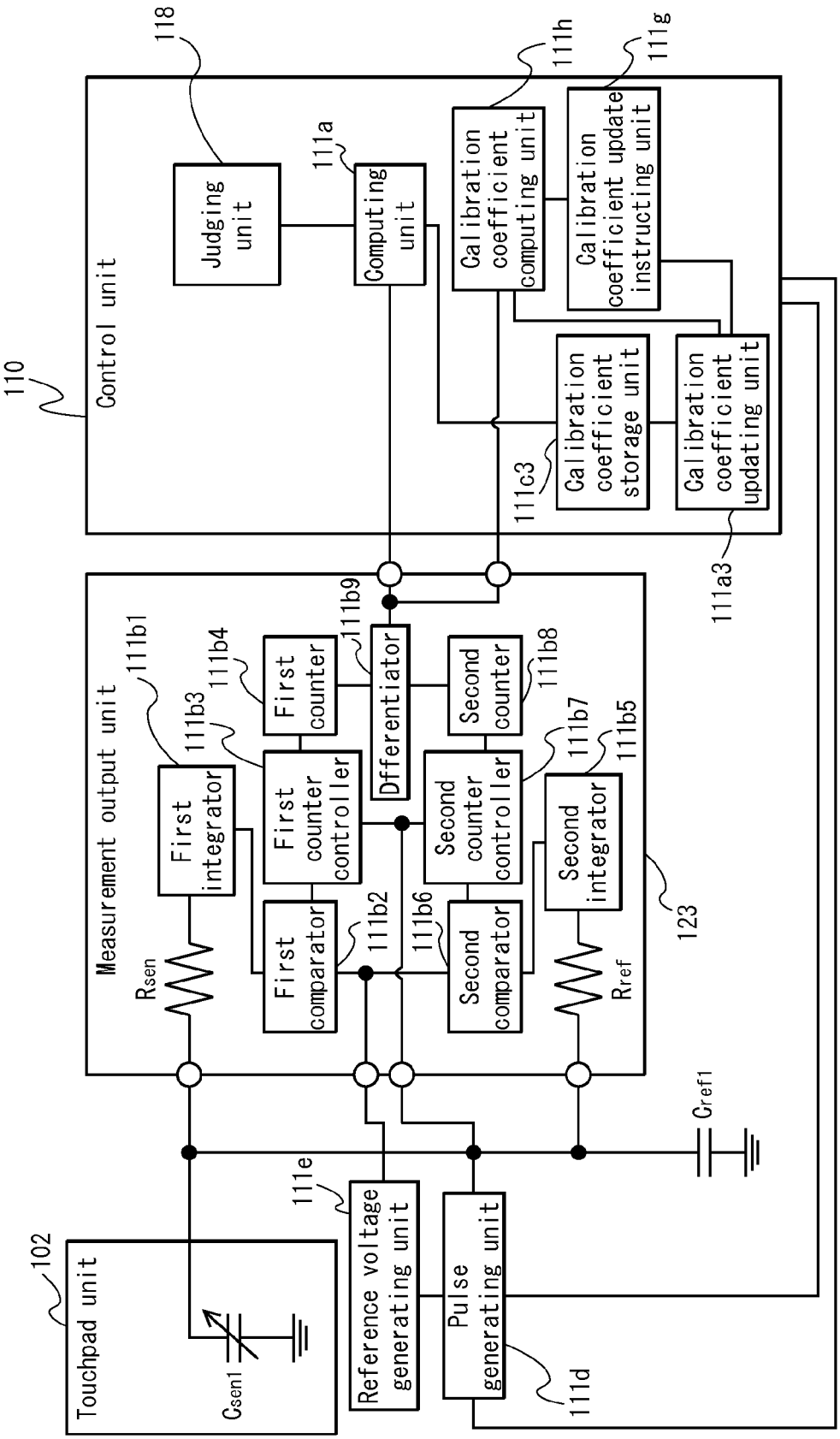

118
111h
111g
111a
Judging unit
Computing unit
Calibration coefficient computing unit
Calibration coefficient update instructing unit
110
Control unit
Calibration coefficient storage unit
Calibration coefficient updating unit
111c3
111a3
111b9
111b1
111b4
Measurement output unit
First integrator
First counter
Dfferentiator
Second counter
111b3
111b8
First counter controller
Second counter controller
111b7
111b5
Second integrator
First comparator
111b2
111b6
Second comparator
123
Rsen
Rref
Cref1
111e
102
Touchpad unit
Reference voltage generating unit
Pulse generating unit
Csen1
111d

FIG. 6

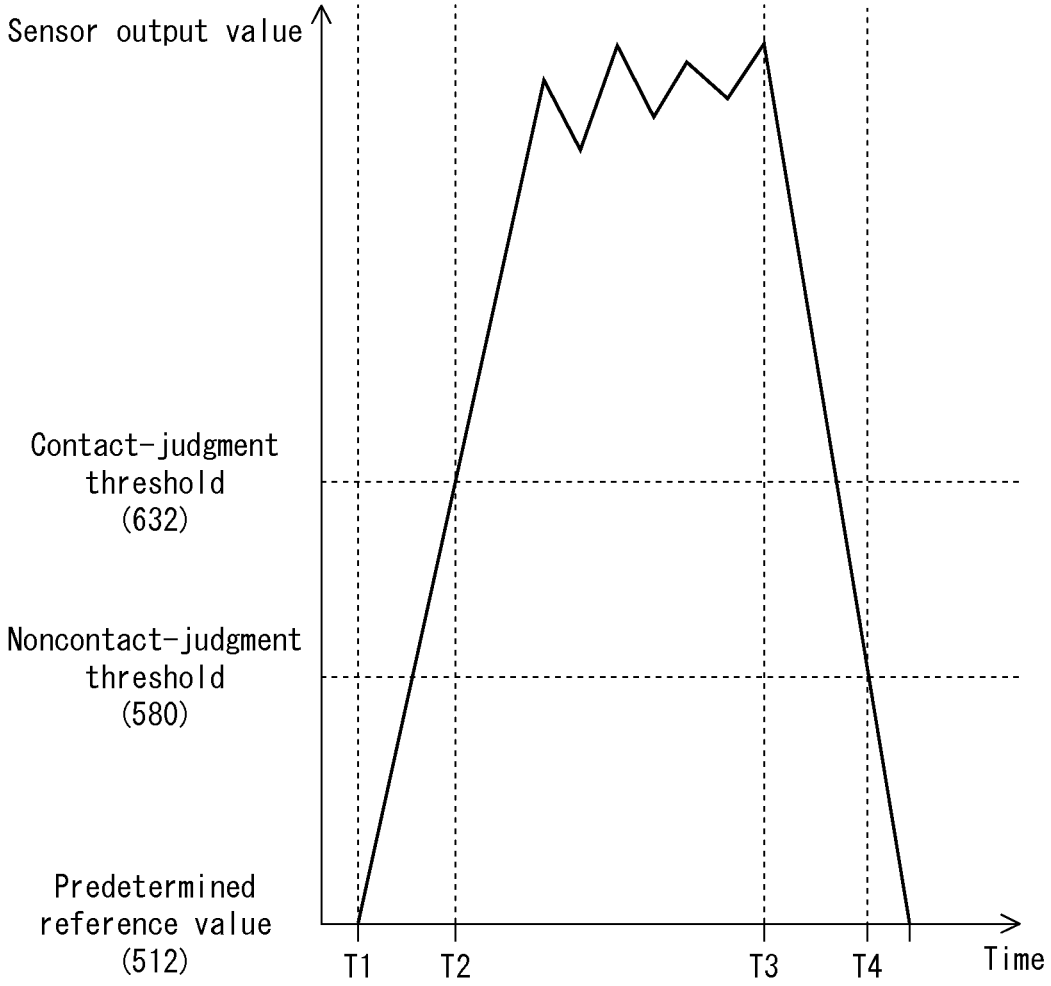

Sensor output value
Contact-judgment threshold (632)
Noncontact-judgment threshold (580)
Predetermined reference value (512)
T1
T2
T3
T4
Time

FIG. 7

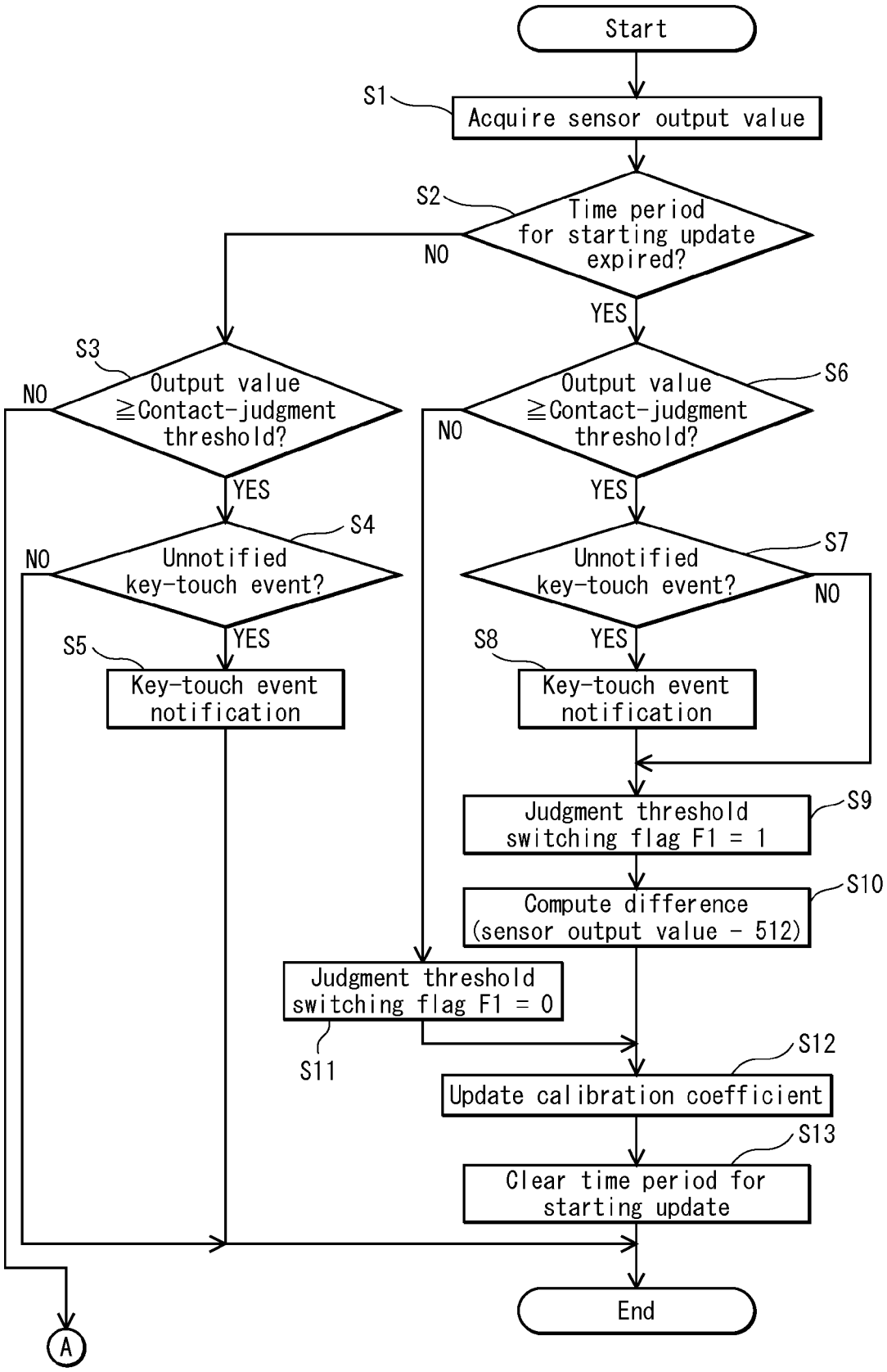

Start
S1
Acquire sensor output value
S2
Time period for starting update expired?
NO
YES
S3
Output value ≧Contact-judgment threshold?
NO
YES
S4
Unnotified key-touch event?
NO
YES
S5
Key-touch event notification
S6
Output value ≧Contact-judgment threshold?
NO
YES
S7
Unnotified key-touch event?
NO
YES
S8
Key-touch event notification
S9
Judgment threshold switching flag F1 = 1
S10
Compute difference (sensor output value - 512)
Judgment threshold switching flag F1 = 0
S11
S12
Update calibration coefficient
S13
Clear time period for starting update
End
A

FIG. 8

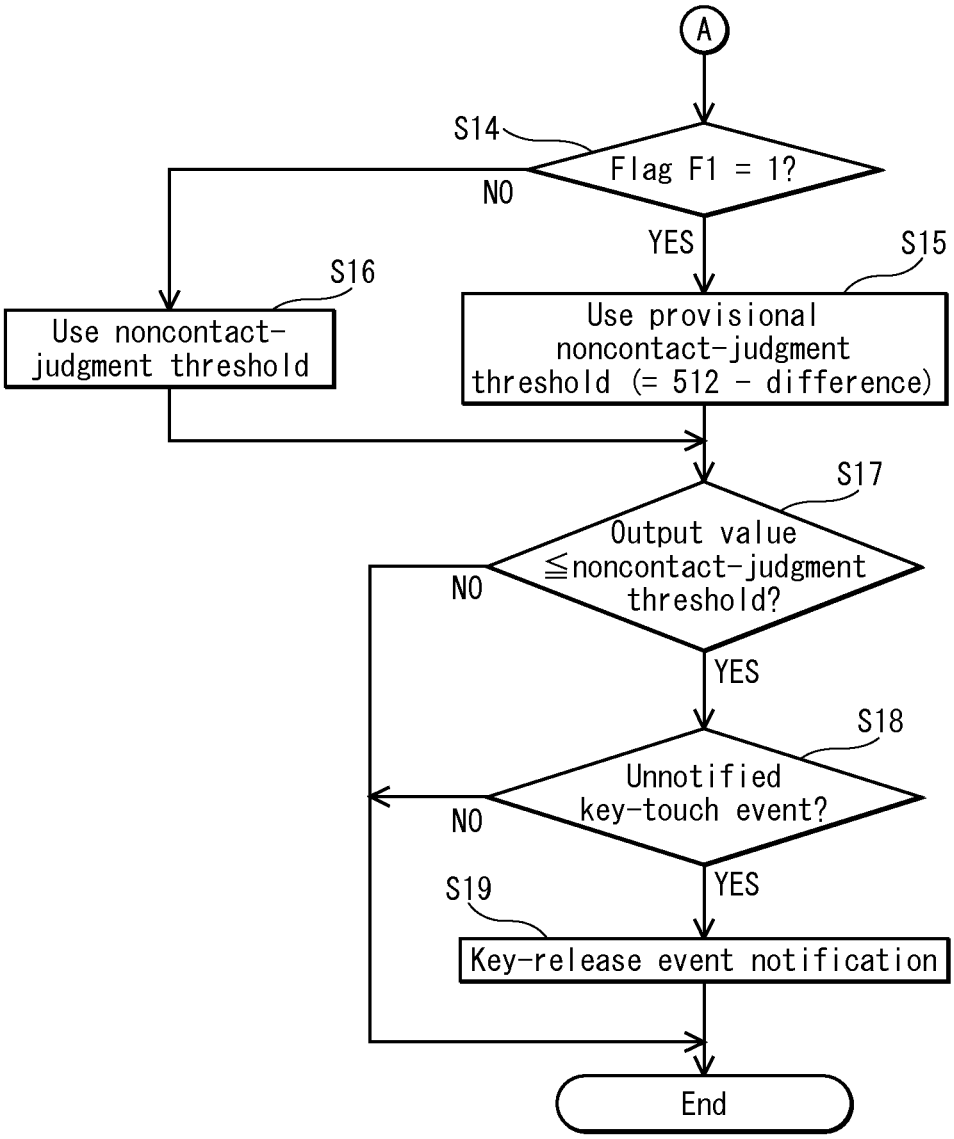

A
S14
Flag F1 = 1?
NO
YES
S15
S16
Use noncontact-judgment threshold
Use provisional noncontact-judgment threshold (= 512 - difference)
S17
Output value ≦noncontact-judgment threshold?
NO
YES
S18
Unnotified key-touch event?
NO
YES
S19
Key-release event notification
End

FIG. 9

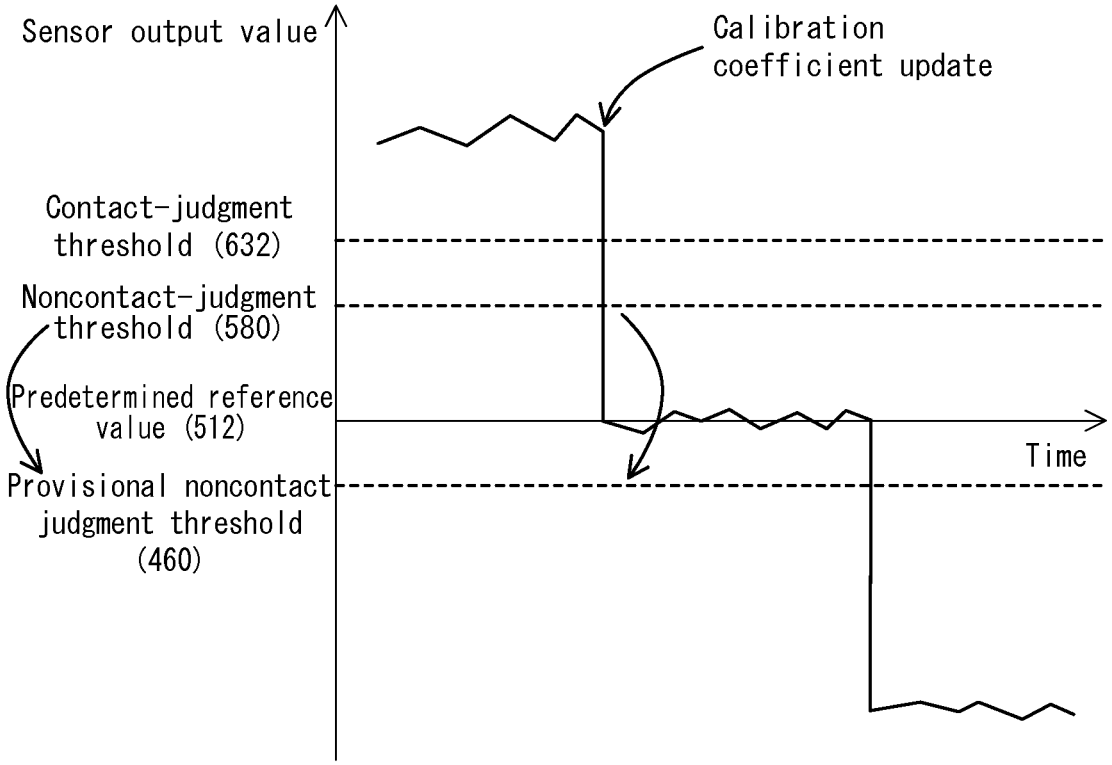

Sensor output value
Calibration coefficient update
Contact-judgment threshold (632)
Noncontact-judgment threshold (580)
Predetermined reference value (512)
Provisional noncontact judgment threshold (460)
Time

FIG. 10A

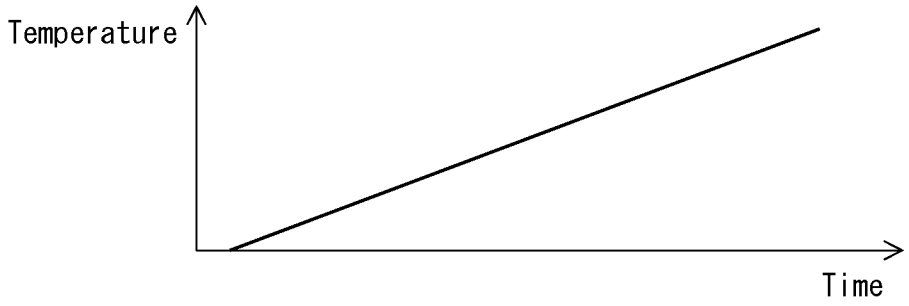


FIG. 10B

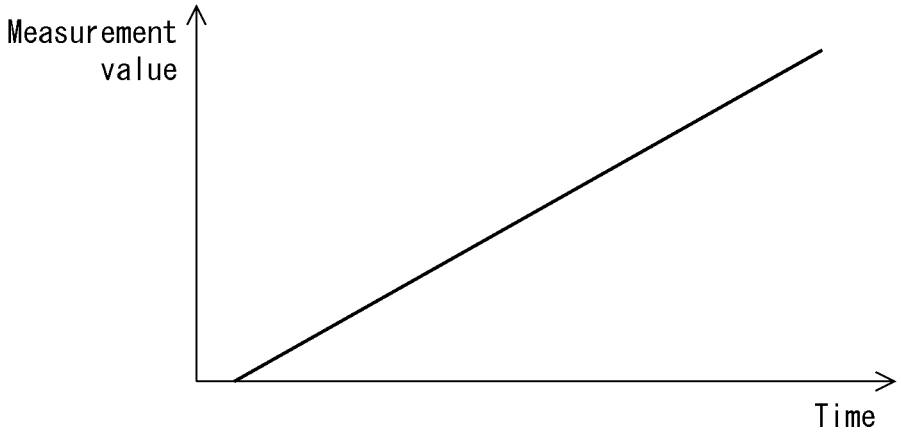


FIG. 10C

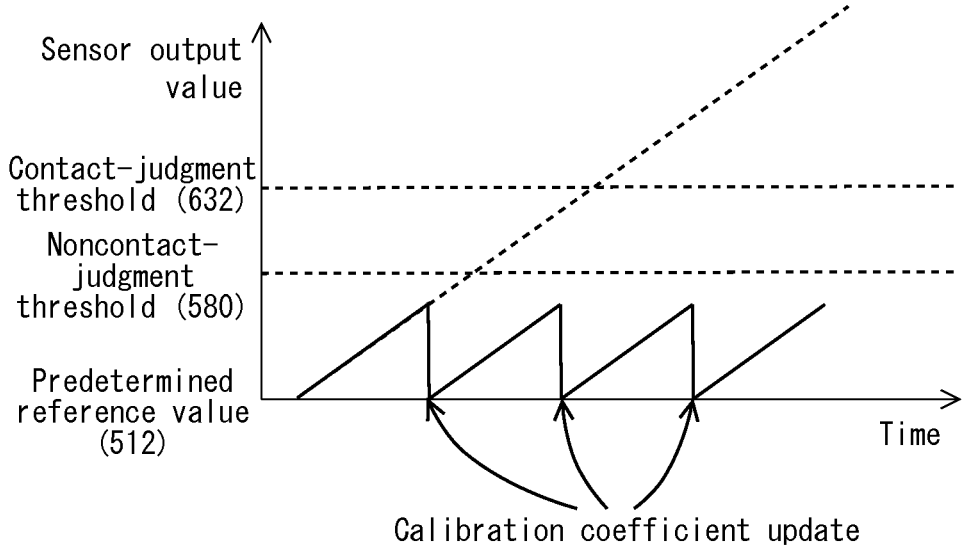


FIG. 11A

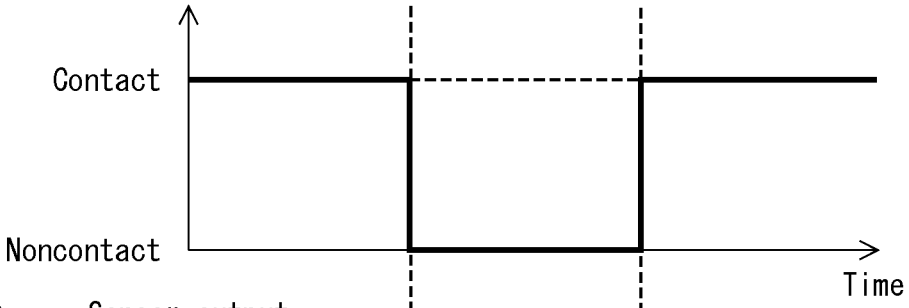


FIG. 11B

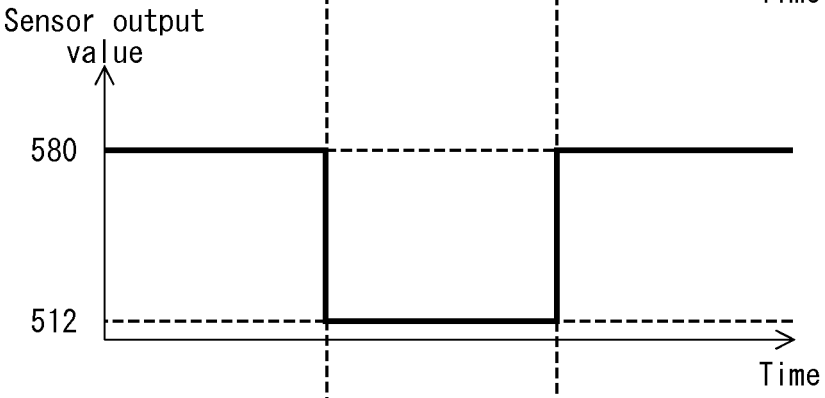


FIG. 11C

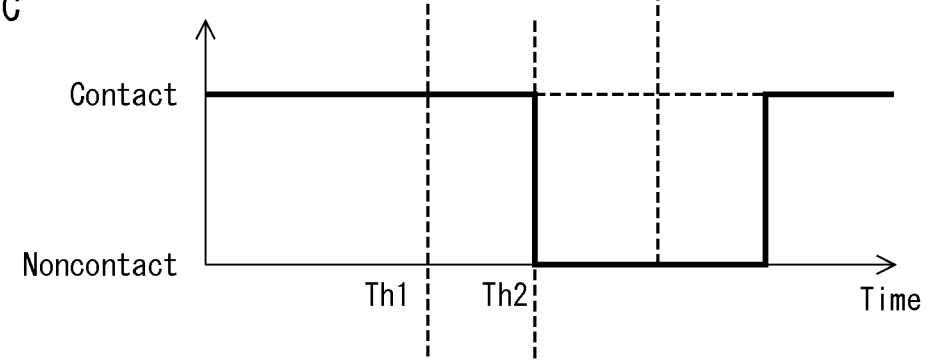
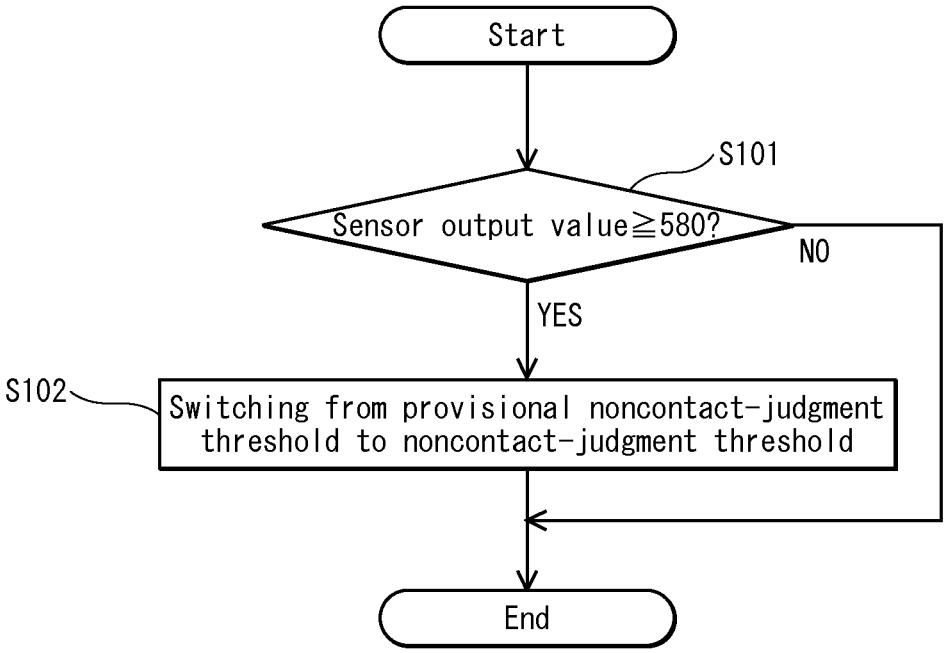


FIG. 12


Start
S101
Sensor output value≧580?
NO
YES
S102
Switching from provisional noncontact-judgment threshold to noncontact-judgment threshold
End

METHOD IN A MOBILE TERMINAL FOR JUDGING A CONTACT BETWEEN AN OPERATING MEMBER AND TOUCHPAD

TECHNICAL FIELD

The present invention relates to mobile terminals having a touchpad unit.

BACKGROUND ART

Mobile terminals provided with a capacitive touchpad unit have been conventionally suggested (see Patent Literature 1). The suggested capacitive touchpad unit measures a change in the capacitance of the touchpad unit at a position corresponding to each key of the touchpad unit to determine whether the key is being touched based on the measurement values.

The measurement values are sensitive to the temperature change in the touchpad unit. Therefore, the measurement values need to be corrected (calibrated) to remove the influence of the temperature change in order to accurately detect a key touch.

In addition, the temperature of the touchpad unit varies from time to time depending on various factors, including the use environment. Therefore, the calibration coefficient used for calibration of measurement values needs to be updated regularly. In addition, the update of the calibration coefficient needs to be carried out in the state where the touchpad unit is not in contact with an operating member in order to eliminate the influencing factors other than the temperature as much as possible.

In view of the above, one conventionally suggested mobile terminal regularly updates the calibration coefficient (updates the reference capacitance value) using a value measured for a key selected from the touchpad keys not in contact with an operating member (see Patent Literature 2).

CITATION LIST

Patent Literature

[Patent Literature 1]
Japanese Patent Application Publication No. 2004-54413
[Patent Literature 2]
Japanese Patent Application Publication No. 2009-265851

SUMMARY OF INVENTION

Technical Problem

With the mobile terminal described in Patent Literature 2, however, the calibration coefficient is left without being updated for a long time in the case where the mobile terminal is used in the state where all the keys constituting the touchpad unit are kept in contact with an operating member (for example, in the case where the mobile terminal is used for a telephone conversation for a long time with the user's face kept in contact with the touchpad unit).

The touchpad unit may undergo a significant temperature change during the time the calibration coefficient is left as it is without update. This results in a risk that a touch to a key is not correctly detected, which may lead to a malfunction.

The present invention is made in view of the above and aims to provide a mobile terminal capable of reducing the occurrence of a malfunction resulting from a temperature change in the touchpad unit.

Solution to Problem

In order to solve the problems noted above, a mobile terminal according to the present invention includes: a touch sensor circuit that includes a capacitive touchpad unit and outputs a measurement value indicating a capacitance for the touchpad unit; a computing unit that computes a sensor output value based on the measurement value output from the touch sensor circuit; an updating unit that updates the sensor output value so as to be equal to a predetermined reference value when the updating unit receives an update instruction; a judging unit that judges that an operating member is in contact with the touchpad unit when a sensor output value is greater than a contact-judgment threshold, and that the operating member is no longer in contact with the touchpad unit when a sensor output value falls below a noncontact-judgment threshold for the first time after the judgment that the operating member is in contact with the touchpad unit; and a judgment threshold switching unit that switches from the noncontact-judgment threshold to be used in a subsequent judgment by the judging unit to a provisional noncontact-judgment threshold for a time period starting when the update takes place while the operating member is in contact with the touchpad unit and ending when the judging unit judges that the operating member is no longer in contact with the touchpad unit.

Advantageous Effects of Invention

The mobile terminal according to the present invention achieves to reduce the occurrence of a malfunction resulting from temperature changes in the touchpad unit.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is the front view showing an external representation of a mobile phone according to an embodiment.

FIG. **2** is a block diagram of the mobile phone according to the embodiment.

FIG. **3** is a schematic view of a touchpad unit according to the embodiment.

FIG. **4** is a view for explaining the operation of a touch sensor circuit according to the embodiment.

FIG. **5** is a block diagram of a measurement output unit according to the embodiment.

FIG. **6** is a view for explaining the operation of a control unit according to the embodiment.

FIG. **7** is a flowchart of the operation of the mobile phone according to the embodiment.

FIG. **8** is a flowchart of the operation of the mobile phone according to the embodiment.

FIG. **9** is a view for explaining the operation of the mobile phone according to the embodiment.

FIGS. **10**A, **10**B, and **10**C are views for explaining the operation of the mobile phone according to the embodiment.

FIGS. **11**A, **11**B, and **11**C are views for explaining the operation of a mobile phone according to a modification.

FIG. **12** is a flowchart of the operation of the mobile phone according to the modification.

DESCRIPTION OF EMBODIMENTS

The following now describes a mobile phone as one embodiment of a mobile terminal according to the present invention.

Embodiment

<1> External Representation

FIG. **1** is the front view showing an external representation of a mobile phone **100** according to the embodiment.

The mobile phone **100** is of a foldable type and has a casing **2**, a sub-LCD **101** and a touchpad unit **102**. The sub-LCD **101** and the touchpad unit **102** are disposed on a surface of the casing **2** to be visible when the mobile phone **100** is in a folded state as shown in FIG. **1**.

On the touchpad unit **102**, marks representing various keys are provided to be visible. By touching the touchpad unit **102** at the location of a mark with a finger or the like, the user can cause the mobile phone **100** to execute a process allocated to the key corresponding to the mark. In addition, in the vicinity of a through hole **104***a* through which the sound from a speaker **105** travels, a face contact detecting key **102***c***3** is disposed not to be visible from the outside.

<2> Structure

As shown in FIG. **2**, the mobile phone **100** includes the sub-LCD **101**, a touch sensor circuit **121** in which the touchpad unit **102** is included, a communication unit **103**, a speaker **104**, a microphone **105**, and a vibrator **106**. In addition, the mobile phone **100** includes a processor and memory, which are not illustrated in the figures. The mobile phone **100** also includes a control unit **110** and an application executing unit **120**, the respective functions of which are realized by the processor executing appropriate programs stored in the memory.

The memory includes a computation buffer (not illustrated) which is used by a calibration coefficient computing unit **111***h* when computing a calibration coefficient.

<2-1> Touch Sensor Circuit

The touch sensor circuit **121** includes the capacitive touchpad unit **102** and a plurality of measurement output units (output units) **123**. Each output unit **123** is electrically connected to one of conductive patterns **102***c***2** and **102***d***2** drawn from the touchpad unit **102** and outputs a calibration coefficient for a measurement value of the capacitance of the touchpad unit **102**.

<2-1-1> Touchpad Unit

As shown in FIG. **3**, the touchpad unit **102** includes: a rectangular substrate **102***d* made of a transparent material (such as glass); a plurality of electrode patterns **102***d***1** disposed on one of surfaces of the substrate **102***d* opposing in the thickness direction; and the conductive patterns **102***d***2** each of which is electrically connected to one of the electrode patterns **102***d***1**. Each of the conductive patterns **102***d***2** is electrically connected to a corresponding one of the measurement output units **123**.

In addition, an electrode pattern **102***c***1** for detecting a contact with the user's face is disposed on the substrate **102***d* at a location near a short edge of the substrate **102***d*. The conductive pattern **102***c***2** is located along a long edge of the substrate **102***d* and connected into the face contact detecting electrode pattern **102***c***1**. Note that the short edge refers to an edge extending to intersect the longitudinal direction, whereas the long edge refers to an edge extending to intersect the widthwise direction. Each conductive pattern **102***c***2** is electrically connected at the other end to a corresponding one of the measurement output units **123**.

The electrode patterns **102***c***1** and **102***d***1** as well as the conductive patterns **102***c***2** and **102***d***2** are made of a transparent conductive material such as ITO (Indium Tin Oxide).

Portions of the touchpad unit **102** corresponding to the electrode patterns **102***c***1** and **102***d***1** serve as the keys described above, including the face contact detecting key and the other keys.

<2-1-2> Measurement Output Units

As shown in FIG. **4**, each of the measurement output unit **123** includes a first counter **111***b***4** that measures the time constant T_{sen} of an RC circuit formed by a capacitor C_{sen} and a resistor R_{sen} and also includes a second counter **111***b***8** that measures the time constant T_g of an RC circuit formed by a chip capacitor C_{ref} and a resistor R_{ref}. Each of the capacitors C_{sen} is formed between a corresponding one of electrode patterns **102***a***1**, **102***b***1**, and **102***c***1** and a wall surface of the casing **2**. The measurement output unit **123** outputs the difference between the time constant T_{sen} and the time constant T_{ref} as a measurement value.

FIG. **5** shows the structure of one of the measurement output unit **123** in detail.

The measurement output unit **123** includes: a first integrator **111***b***1** that is connected to the capacitor C_{sen}, which is formed with a corresponding one of the electrode patterns **102***d***1** and **102***c***1**, as well as to a pulse generating unit **111***d* both via the resistor R_{sen}; a first comparator **111***b***2** that compares the input voltages from the first integrator **111***b***1** and from a reference voltage generating unit **111***e* to output a predetermined voltage when the two input voltages are equal; a second integrator **111***b***5** that is connected to the reference capacitor C_{ref} as well as to the pulse generating unit **111***d* both via the resistor R_{ref}; and a second comparator **111***b***6** that compares the input voltages form the second integrator **111***b***5** and from the reference voltage generating unit **111***e* to output a predetermined voltage if the two input voltages are equal.

In addition, the measurement output unit **123** also includes: a first counter controller **111***b***3** that controls, based on the input voltages from the first comparator **111***b***2** and from the pulse generating unit **111***d*, the timing for causing the first counter **111***b***4** to start and stop counting; a second counter controller **111***b***7** that controls, based on the input voltages from the second comparator **111***b***6** and from the pulse generating unit **111***d*, the timing for causing the second counter **111***b***8** to start and stop counting; and a differentiator **111***b***9** that outputs the difference between the count value of the first counter **111***b***4** and the count value of the second counter **111***b***8**. Note that the reference capacitor C_{ref} is disposed at a location where the heat dissipation is high in order to suppress the variations in capacitance resulting from a temperature change.

An increase in the capacitance of each capacitor C_{sen} formed with one of the electrode patterns **102***c***1** and **102***d***1** of the touchpad unit **102** leads to an increase in the time constant T_{sen}, which results in a larger measurement value. On the contrary, a decrease in the capacitance of each capacitor C_{sen} leads to a decrease in the time constant T_{sen}, which results in a smaller measurement value. For example, when an operating member makes contact with the touchpad unit **102**, the capacitance of a relevant one of the capacitor C_{sen} increases, which results in an increase in the measurement value. The variations in the capacitance of the reference capacitor C_{ref} are small enough to be negligible, as compared to that of the capacitor C_{sen}. Therefore, the time constant T_{ref} can be regarded as a constant value.

<2-2> Control Unit

In addition to the functions of a typical mobile phone, the control unit **110** functions as an OS (Operating System) that notifies the application executing unit **120** of an event containing identification information of a key determined by a key determining unit **113**. The control unit **110** includes a

judging unit **118**, a judgment threshold switching unit **133**, an event notifying unit **114**, an audio processing unit **115**, a display control unit **116**, a computing unit **111***a*, a calibration coefficient computing unit **111***h*, a calibration coefficient update instructing unit (instructing unit) **111***g*, a timer unit **134**, a calibration coefficient updating unit **111***a***3**, a calibration coefficient storage unit **111***c***3**, and an information holding unit **131** that holds identification information received from the judging unit **118**.

<2-2-1> Computing Unit

The computing unit **111***a* corrects a measurement value input from each measurement output unit **111***b* using a relevant calibration coefficient stored in the calibration coefficient storage unit **111***c*. This process of correcting a measurement value is also called a calibration.

The computing unit **111***a* computes a sensor output value from a measurement value using Equation (1).

$$I(t)=Is(t)-A1 \quad \text{[Equation 1]}$$

where t denotes a time variable, I(t) denotes a sensor output value to be output from the computing unit **111***a*, Is(t) denotes a measurement value, and A**1** denotes a calibration coefficient.

<2-2-2> Calibration Coefficient Storage Unit

The calibration coefficient storage unit **111***c***3** is formed by an area of memory and stores the calibration coefficient A**1** used in the Equation (1). The calibration coefficient A**1** is used to compute a sensor output value from a measurement value output from each measurement output unit **123** that is electrically connected to a corresponding one of the electrode patterns **102***d***1** and **102***c***1** of the touchpad unit **102**.

<2-2-3> Calibration Coefficient Updating Unit

The calibration coefficient updating unit **111***a***3** updates the calibration coefficient A**1** stored in the calibration coefficient storage unit **111***c***2**. The calibration coefficient updating unit **111***a***3** updates the calibration coefficient A**1** stored in the calibration coefficient storage unit **111***c* in a manner that the sensor output value computed at the time of receiving an instruction for updating the calibration coefficient from the control unit **110** becomes equal to a predetermined reference value. In one example, the predetermined reference value may be a center value of the range of sensor output values (i.e., to "512" when the sensor output values are up to "1024").

The calibration coefficient updating unit **111***a***3** computes, as the calibration coefficient A**1**, the difference between the sensor output value at the update time T and the predetermined reference value, by using Equation (2) below.

$$A1=Is(T)-I0 \quad \text{[Equation 2]}$$

where, T denotes the update time, and I**0** denotes the predetermined reference value notified from the calibration coefficient computing unit **111***h*, which will be described later.

<2-2-4> Judging Unit

On receiving a timeout notification, which will be described later, from the timer unit **134**, the judging unit **118** compares the sensor output value acquired from the computing unit **111***a* with a contact-judgment threshold. If the sensor output value exceeds the contact-judgment threshold, the judging unit **118** judges that a corresponding key (hereinafter, such a key is referred to as a "target key") is in contact with an operating member. The judging unit **118** acquires the sensor output values at a predetermined cycle (every 40 ms, for example) and notifies the event notifying unit **114** of the identification information identifying the target key specified based on the sensor output values.

On the other hand, when the sensor output value once exceeds the contact-judging threshold and subsequently falls below the noncontact-judgment threshold, the judging unit **118** judges that the touch to the target key is released. Then, the judging unit **118** checks a judgment threshold switching flag F**1**, which will be described later, held by the judgment threshold switching unit **133**. When the judgment threshold switching flag F**1** is set to "0", the judging unit **118** uses a noncontact-judgment threshold and uses a provisional noncontact-judgment threshold when the judgment threshold switching flag F**1** is set to "1". Note that all of the contact-judgment threshold, noncontact-judgment threshold, and provisional noncontact-judgment threshold are stored in advance in a threshold storage area of the memory. The values of the respective thresholds are determined in advance by experiments, for example.

In addition, the judging unit **118** judges that the face contact detecting key is being touched when the sensor output value corresponding to the face contact detecting key exceeds the contact-judgment threshold. In such a case, the judging unit **118** suspends the process of notifying the event notifying unit **114** of identification information indicating any key other than the face contact detecting key. With this operation, a touch operation to any key is disabled during the time, for example, the user's face is in contact with the face contact detecting key (that is, during a phone conversation). This is effective to prevent malfunction during a phone call.

The following now describes the operation of the judging unit **118** from the time when an operating member makes a contact with a key to the time when the touch is released.

In FIG. **6**, the horizontal axis represents the time, whereas the vertical axis represents the sensor output value. In the figure, the range of the sensor output value from 0 to 511 is omitted. In the example shown in FIG. **6**, the predetermined reference value is set to 512, the contact-judgment threshold is set to 632, and the noncontact-judgment threshold is set to 580.

The time T**1** indicates the time at which the operating member makes a contact with the touchpad unit **102**. As shown in FIG. **6**, when the operating member makes a contact at the time T**1**, the sensor output value starts to increase. Then, the sensor output value exceeds the contact-judgment threshold at the time T**2**. At this point in time, the judging unit **118** judges that an operating member is in contact with the touchpad unit **102**.

Subsequently, the sensor output value starts to decrease as the operating member starts to move away from the touchpad unit **102** at the time T**3** and falls below the noncontact-judgment threshold at the time T**4**. At this point in time, the judging unit **118** judges that the operating member is no longer in contact with the touchpad unit **102**.

<2-2-5> Calibration Coefficient Update Instructing Unit

The calibration coefficient update instructing unit **111***g* issues a calibration coefficient updating instruction for updating the calibration coefficient A**1** stored in the calibration coefficient storage unit **111***c*, to the calibration coefficient computing unit **111***h*, the calibration coefficient updating unit **111***a***3**, and the judgment threshold switching unit **133**.

<2-2-6> Calibration Coefficient Computing Unit

On receiving the calibration coefficient updating instruction from the calibration coefficient updating instructing unit **111***g*, the calibration coefficient computing unit **111***h* notifies the calibration coefficient updating unit **111***a***3** of the sensor output value computed based on the measurement value that is output at the time when the calibration coefficient updating instruction is received from the measurement output unit **123**.

<2-2-7> Judgment Threshold Switching Unit

The judgment threshold switching unit **133** switches from the noncontact-judgment threshold to the provisional noncontact-judgment threshold, and vice versa. The noncontact-judgment threshold and the provisional noncontact-judgment threshold are used by the judging unit **118** to detect a touch to the touchpad unit **103** made by an operating member. Here, the judgment threshold switching unit **133** holds the judgment threshold switching flag F**1** and sets the judgment threshold switching flag F**1** to "1" when switching from the noncontact-judgment threshold to the provisional noncontact-judgment threshold.

<2-2-8> Timer Unit

The timer unit **134** includes a timer and measures how much time has elapsed since the judging unit **118** acquires the sensor output value. The timer unit **134** issues a timeout notification upon the expiration of a predetermined time period.

<2-2-9> Information Holding Unit

The information holding unit **131** is implemented as an area of the memory and stores identification information of the target key written by the judging unit **118**. Here, the judging unit **118** writes identification information of a target key each time a sensor output value is acquired.

<2-2-10> Event Notifying Unit

The event notifying unit **114** notifies the application executing unit **120** of event occurrence information that contains the identification information received from the judging unit **118**. In addition, the event notifying unit **114** reads identification information of a target key from the information holding unit **131** if there is an event notification being processed when the sensor output value falls below the noncontact-judgment threshold upon the calibration coefficient update and notifies the application executing unit **120** of the event occurrence information that contains the identification information thus read.

<2-2-11> Others

The sub-LCD **101** displays images of characters and the like under the control by the control unit **110**.

The communication unit **103** is a circuit that transmits radio waves to and from a base station via an antenna. The communication unit **103** passes a reception signal to the control unit **110** after demodulation and transmits a signal passed from the control unit **110** after modulation.

The audio processing unit **115** carries out D/A (Digital/Analog) conversion of an audio signal received via the communication unit **103** to output the resulting signal from the speaker **104** and also carries out A/D (Analog/Digital) conversion of an audio signal input from the microphone **105** to transmit the resulting signal via the communication unit **103**. Note that the audio signals mentioned above include DTMF (Dial Tone Multi Frequency) tones.

The display control unit **116** controls the sub-LCD **101** to display images and the like, by following instructions from the application executing unit **120**.

The application executing unit **120** executes an appropriate application according to the event occurrence information received from the control unit **110**.

<3> Operation

<3-1> Overall Operation

FIGS. **7** and **8** show a flowchart of the operation of the mobile phone **100** according to the embodiment.

First, the judging unit **118** acquires sensor output values each computed based on a measurement value output from the touch sensor circuit **121** (Step S**1**). Note that the judging unit **118** cyclically (every 40 ms, for example) acquires the sensor output value output from the computing unit **111***a*.

Thereafter, the timer unit **134** judges whether the condition for starting the calibration coefficient update process is met (Step S**2**). Note the condition is met upon the expiration of the predetermined time period.

When the timer unit **134** judges in Step S**2** that the predetermined time period has passed and thus the condition for starting the calibration coefficient update process is met (Step S**2**: YES), the judging unit **118** judges whether the sensor output value is equal to or greater than the contact-judgment threshold (Step S**6**).

When judging in Step S**6** that the sensor output value is smaller than the contact-judgment threshold (Step S**6**: NO), the judging unit **118** sets the judgment threshold switching flag F**1** to "0" (Step S**11**). Then, the processing moves on to Step S**12**, which will be described later.

On the other hand, when judging in Step S**6** that the sensor output value is equal to or greater than the contact-judgment threshold (Step S**6**: YES), the judging unit **118** notifies the event notifying unit **114** of the situation. In response, the event notifying unit **114** judges whether event occurrence information that contains the identification information received from the judging unit **118** has already been issued to the application executing unit **120** (that is, whether the key touch event has been notified to the application executing unit) (Step S**7**).

On judging in Step S**7** that the key touch event has not been notified yet, the event notifying unit **114** notifies the application executing unit **120** of the key touch event (Step S**8**). Also, if the key touch event has not been notified yet, the processing moves onto Step S**9**.

Subsequently, the judgment threshold switching unit **133** sets the judgment threshold switching flag F**1** to "1" (Step S**9**).

Next, the calibration coefficient computing unit **111***h* computes, as the calibration coefficient A**1**, the difference between the sensor output value and the predetermined reference value (which is "512" in this embodiment) (Step S**10**).

Then, the calibration coefficient update instructing unit **111***g* issues a calibration coefficient updating instruction to the calibration coefficient updating unit **111***a***3** and, in response, the calibration coefficient updating unit **111***a***3** updates the calibration coefficient A**1** stored in the calibration coefficient storage unit **111***c* (Step S**12**). As a result of this step, the calibration coefficient updating unit **111***a***3** updates the calibration coefficient A**1** in a manner that with the updated calibration coefficient A**1**, the sensor output value is calibrated to the value equal to the predetermined reference value as shown in FIG. **9**.

Subsequently, the timer unit **134** clears the passage of time having been measured to determine the timing for the calibration coefficient update (Step S**13**).

On the other hand, when the timer unit **134** judges in Step S**2** that the predetermined time period has not passed yet and thus the condition for starting the calibration coefficient update process has not been met yet (Step S**2**: NO), the judging unit **118** then judges whether the sensor output value is equal to or greater than the contact-judgment threshold (Step S**3**).

When the judging unit **118** judges in Step S**3** that the sensor output value is equal to or greater than the contact-judgment threshold, the event notifying unit **114** judges whether event occurrence information generated from the identification information received from the judging unit **118** has already been issued to the application executing unit **120** (that is, whether the key touch event has been notified to the application executing unit) (Step S**4**).

On judging in Step S4 that the key touch event has not been notified yet, the event notifying unit **114** notifies the application executing unit **120** of the key touch event (Step S5). Also, if the key touch event has not been notified yet, the processing ends without any further steps.

In Step S3, when the judging unit **118** judges that the sensor output value is smaller than the contact-judgment threshold (Step S3: NO), the judgment threshold switching unit **133** judges whether the judgment threshold switching flag F1 is set to "1" or not (Step S14).

On judging in Step S14 that the judgment threshold switching flag F1 is not set to "1" (Step S14: No), the judgment threshold switching unit **133** leaves the noncontact-judgment threshold unchanged (Step S16).

On the other hand, when it is judged in Step S14 that the judgment threshold switching flag F1 is set to "1" (Step S14: YES), the judgment threshold switching unit **133** then switches the noncontact-judgment threshold to the difference between the predetermined reference value "512" and the sensor output value computed by the calibration coefficient computing unit **111***h* (that is, the difference is equal to the value equal to the calibration coefficient A1) (Step S15).

Next, the judging unit **118** judges whether the sensor output value is equal to or smaller than the noncontact-judgment threshold (Step S17).

When the judging unit **118** judges in Step S17 that the sensor output value exceeds the noncontact-judgment threshold (Step S17: NO), the processing ends without any further steps.

On the other hand, when the judging unit **118** judges in Step S17 that the sensor output value is equal to or smaller than the noncontact-judgment threshold (Step S17: YES), the event notifying unit **114** judges whether the key touch event has been notified (Step S18).

When the event notifying unit **114** judges in Step S18 that the key touch event has not been notified yet (Step S18: NO), the processing ends without any further steps.

On the other hand, on judging in Step S18 that the key touch event has been notified to the application executing unit **120** (Step S18: YES), the event notifying unit **114** then notifies the application executing unit **120** of a key release event (i.e., an event occurring when the target key is released) (Step S19). Then the processing ends.

Through the above steps, even if the ambient temperature of the touchpad unit **102** elevates (see FIG. **10**A) and the temperature rise results in that measurement values output from the measurement output unit **123** are higher than otherwise they would be (see FIG. **10**B), the calibration coefficient A1 is updated at regular intervals (every 40 ms, for example) (see FIG. **10**C). Owing to the calibration coefficient A1 being regularly updated, it is duly avoided that the sensor output values exceed the contact-judgment threshold although the touchpad unit **102** is not in contact with any operating member.

<Modifications>

Up to this point, the mobile terminal according to the present invention has been described by way of the specific embodiment. However, it goes without saying that various modifications including the following are duly possible and the present invention is not limited to the mobile phone described above in the specific embodiment.

(1) In the above embodiment, the judging unit **118** uses the provisional noncontact-judgment threshold if the judgment threshold switching flag F1 is set to "1". However, this is merely one example and without limitation. For example, it is applicable to switch from the provisional noncontact-judgment threshold back to the noncontact-judgment threshold when the sensor output value equal to a predetermined value or larger is output after the noncontact-judgment threshold is switched to the provisional noncontact-judgment threshold.

In the above embodiment, it is presumed that the calibration coefficient A1 is updated using either a sensor output value that is output when the touchpad unit is in contact with an operating member or a sensor output value that is output when the touch pad unit is not in contact with an operating member. However, as shown in FIG. **11**, there may be a time lag between the time-varying change of the actual sensor output value and the time-varying change of the sensor output value recognized by the judging unit **118**. That is, there may be a case where the calibration coefficient A1 is updated at the time when the judging unit **118** judges that an operating member is currently in contact with the touchpad unit **102** but actually the operating member has already been moved away from the touchpad unit **102** (for example, between the time Th1 and Th2 shown in FIG. **11**). The consequence is that the judgment threshold switching unit **133** switches from the noncontact-judgment threshold to the provisional contact-judgment threshold (for example, "480" which is smaller than the predetermined reference value "512") despite that the calibration coefficient A1 is computed under the state where the operating member is not in contact with the touchpad unit **102**.

As a consequence, the calibration coefficient is updated so that the sensor output value is commuted to be equal to "512", which is the predetermined reference value taken under the state where the operating member is not in contact with the touchpad unit **102**. This means that the sensor output value never falls below the provisional noncontact-judgment threshold, which makes it impossible to detect removable of the operating member from the touchpad unit **102**.

According to this modification, however, the provisional noncontact-judgment threshold is switched back to the noncontact-judgment threshold if the sensor output value obtained by the judgment threshold switching unit **133** after switching from the noncontact-judgment threshold to the provisional noncontact-judgment threshold is equal to or greater than a predetermined value (hereinafter, referred to as the second reference value) of "580", for example.

FIG. **12** is a flowchart of the operation of the mobile phone according to the modification.

The following description is given on the precondition that the second reference value is set to "580".

First, the judging unit **118** acquires a sensor output value from the computing unit **111***a* and judges whether the sensor output value is equal to or greater than "580" that is the second reference value (Step S101).

In Step S101, the judging unit **118** judges that the sensor output value is smaller than the second reference value of "580" and notifies the judgment threshold switching unit **133** of the situation. In response, the judgment threshold switching unit **133** ends the process without switching to the provisional noncontact-judgment threshold.

On the other hand, when judging in Step S101 that the sensor output value is equal to or greater than the second reference value of "580", the judging unit **118** notifies the judgment threshold switching unit **133** of the situation. In response, the judgment threshold switching unit **133** switches from the provisional noncontact-judgment threshold to the noncontact-judgment threshold (Step S102) and then processing ends.

Through the above processing steps, it is ensured that the judgment threshold switching unit **133** changes the noncontact-judgment threshold to an appropriate value. Conse-

quently, it duly is avoided that the removal of the operating member from the touchpad unit **102** cannot be detected.

(2) According to the above embodiment, when a calibration coefficient update instruction is received from the calibration coefficient update instructing unit **111***g*, the calibration coefficient computing unit **111***h* outputs the sensor output value that is computed at the time when the calibration coefficient update instruction is received. However, this is merely an example and without limitation. For example, it is applicable that calibration coefficient computing unit **111***h* outputs the average of a predetermined number of sensor output values sampled up to the time at which the calibration coefficient update instruction is received from the calibration coefficient update instructing unit **111***g*.

Since the average value is used according to this modification, the accuracy of the sensor output value is further enhanced.

(3) According to the above embodiment, the sensor output values from the measurement output units become higher when an operating member is in contact with the touchpad unit **102**. However, this is merely an example and without limitation. For example, the present invention is applicable to the case where the sensor output values from the measurement output unit **123** become lower when an operating member is in contact with the touchpad unit **102**.

(4) The mobile phone described in the above embodiment may be of any type as long as the mobile phone is provided with a touchpad unit. For example, the mobile phone may be of a foldable type along a long side or along a short side, a non-foldable type, a slidable, type, and so on.

(5) According to the above embodiment, the sub-LCD **101** and the touchpad unit **102** are described as two separate components. However, the sub-LCD **101** and the touchpad unit **102** may be combined into one component that functions as both, i.e., a so-called touch panel.

That is, one touch panel may function as both the operating portion and the display portion for displaying a numeral, character, or the like input by a touch operation. Alternatively, the operating portion used to input a numeral or character may be implemented by a touch panel and the display portion used for displaying an input numeral, character, or the like may be implemented by an LCD, organic EL (Electro-Luminescence), or the like.

In addition, the touchpad unit is not limited to the type that employs an LCD capable of displaying images to present characters and the like. Alternatively, the touchpad unit may be a combination of an illuminator and a sheet having transmitting parts each in a shape of a character or mark disposed over the illuminator. In this alternative configuration, the user may touch the sheet at a location corresponding to the transmitting part having the shape of a desired character. In response, a change is caused in the capacitance of the touchpad unit, so that the desired character is input.

(6) In the above embodiment, the predetermined reference value is set to "512", the noncontact-judging threshold is set to "580", and the contact-judging threshold is set to "632, but these values are merely examples and without limitations. In addition, although the touchpad unit is not in contact with any operating member, the sensor output value varies due to noise resulting from the operations of the various function units used for placing a call or actuating a camera function. It is therefore preferable to carry out measurements in advance see how much the sensor output values and key contact values increase during the time of a phone conversation or a picture-taking operation and determine the values of the noncontact-judging threshold and contact-judging threshold based on the measurements.

(7) Part or entirety of the touch sensor circuit according to the embodiment may be implemented by an integrated circuit composed of a single-chip or a plurality of chips. The control unit **110** according to the embodiment described above may be implemented by a computer program alone or by a combination of a plurality of chips constituting an integrated circuit.

(8) To implement the control unit **110** described in the above embodiment, the program for causing the CPU to run may be distributed via recording mediums or via various communication channels. Examples of such recording mediums include IC card, optical disc, flexible disc, ROM, and flash memory. The program distributed may be stored onto memory readable by a CPU included in a device to be available for use. The functionally of the control unit **110** described in the above embodiment is realized by the CPU executing the program.

<Supplemental>

(1) A mobile phone according to an embodiment is provided with a capacitive touchpad **102** and includes: a touch sensor circuit **121** that outputs a measurement value indicating a capacitance for the touchpad unit **102**; a computing unit **111***a* that computes a sensor output value by correcting a measurement value output from the touch sensor circuit by using a calibration coefficient; a calibration coefficient updating unit **111***a***3** that updates the calibration coefficient when an update instruction for updating the calibration coefficient is received from an external source, so that the sensor output value computed by using the updated calibration coefficient becomes equal to a predetermined reference value; a judging unit **118** that judges that an operating member is in contact with the touchpad unit **102** when a sensor output value computed before the update of the calibration coefficient is greater than a contact-judgment threshold, and that the operating member is no longer in contact with the touchpad unit **102** when a sensor output value falls below a noncontact-judgment threshold for the first time after the judgment that the operating member is in contact with the touchpad unit **102** is made; and a judgment threshold switching unit **133** that switches from the noncontact-judgment threshold to be used in a subsequent judgment by the judging unit to a provisional noncontact-judgment threshold for a time period starting when the update of the calibration coefficient takes place while the operating member is in contact with the touchpad unit **102** and ending when the judging unit **118** judges that the operating member is no longer in contact with the touchpad unit **102**.

With this configuration, when the calibration coefficient updating unit **111***a***3** updates the calibration coefficient in the state where the touchpad unit **102** is in contact with the user's face, the judgment threshold switching unit **133** causes the judging unit **118** to make a judgment with the use of the provisional noncontact-judging threshold. That is, the judging unit **118** is enabled to properly judge whether the touchpad unit **102** is in contact with part of the user's face and therefore the calibration coefficient is updated at short intervals even if the touchpad unit **102** is in contact with the user's face for a long period of time. Consequently, the influence on changes of the capacitance resulting from the temperature change is suppressed, which leads to prevention of malfunction resulting from the temperature change of the touchpad unit **102**.

(2) The mobile telephone according to the embodiment may further include: a calibration coefficient update instructing unit **111***g* that repeatedly issues an update instruction for updating the calibration coefficient to the calibration coefficient updating unit; and a calibration coefficient storage unit

111*c* for storing the calibration coefficient. The calibration coefficient updating unit **111***a***3** carries out the update so that the sensor output value computed based on the measurement value that is output at a time when the update instruction from the calibration coefficient update instructing unit **111***g* is received results in a value equal to the reference value.

With the provision of the calibration coefficient storage unit **111***c* for storing a calibration coefficient, the predetermined reference value for sensor output values is easily changed simply by the calibration coefficient updating unit **111***a***3** updating the calibration coefficient stored in the calibration coefficient storage unit **111***c*.

(3) The mobile telephone according to the embodiment may further include a timer unit **134** that measures a time period having passed after the judging unit **118** receives the sensor output value. The calibration coefficient update instructing unit **111***g* issues the instruction to update the calibration coefficient when the measured time period reaches a predetermined time period.

With this configuration, even during the time that the touchpad unit **102** remains in contact with an operating member, the calibration coefficient update instructing unit **111***g* issues an instruction for updating the calibration coefficient. This leads to that the calibration coefficient is reliably updated even under the state where the touchpad unit **102** is in contact with the operating member for a long time, so that malfunction resulting from temperature change of the touchpad unit **102** is prevented.

INDUSTRIAL APPLICABILITY

The mobile terminal according to the present invention is usable for the cases where a user makes operation with the touchpad unit.

REFERENCE SIGNS LIST

1, **2** casing
3 input key
4 LCD
100 mobile phone
101 sub-LCD
102 touchpad unit
103 communications unit
104 speaker
105 microphone
106 vibrator
110 control unit
111*a* computing unit
111*a***3** calibration coefficient updating unit (updating unit)
111*c* calibration coefficient storage unit (storage unit)
111*g* calibration coefficient update instructing unit (update instructing unit)
111*h* calibration coefficient computing unit
114 event notifying unit
115 audio processing unit
116 display control unit
120 application executing unit
121 touch sensor circuit
123 measurement output unit (output unit)
133 judgment threshold switching unit
134 timer unit

The invention claimed is:

1. A mobile terminal comprising:
a touch sensor circuit that includes a capacitive touchpad unit and outputs a measurement value indicating a capacitance for the touchpad unit;
a computing unit that computes a sensor output value based on the measurement value output from the touch sensor circuit;
an updating unit that updates the sensor output value so as to be equal to a predetermined reference value when the updating unit receives an update instruction;
a judging unit that judges that
an operating member is in contact with the touchpad unit when a sensor output value is greater than a contact-judgment threshold, and
the operating member is no longer in contact with the touchpad unit when a sensor output value falls below a noncontact-judgment threshold for a first time after the judgment that the operating member is in contact with the touchpad unit; and
a judgment threshold switching unit that switches from the noncontact-judgment threshold to be used in a subsequent judgment by the judging unit to a provisional noncontact-judgment threshold for a time period starting when the update takes place while the operating member is in contact with the touchpad unit and ending when the judging unit judges that the operating member is no longer in contact with the touchpad unit, and switches from the provisional noncontact-judgment threshold back to the noncontact-judgment threshold after the time period.

2. The mobile terminal according to claim **1**, further comprising:
an update instructing unit that issues an update instruction to the updating unit, wherein
the update unit carries out the update so that the sensor output value based on the measurement value output at a time when the update unit receives the update instruction from the update instructing unit is computed to be equal to the reference value.

3. The mobile terminal according to claim **2**, further comprising:
a timer unit that measures a time period having passed after the judging unit receives the sensor output value,
wherein the update instructing unit issues the update instruction when the measured time period reaches a predetermined time period.

4. The mobile terminal according to claim **1**, wherein the judgment threshold switching unit switches from the provisional noncontact-judgment threshold back to the noncontact-judgment threshold when a sensor output value computed by the computing unit after switching from the noncontact-judgment threshold to the provisional noncontact-judgment threshold is equal to or greater than a predetermined value.

5. A method for controlling a mobile terminal that includes a touch sensor circuit, the touch sensor circuit including a capacitive touchpad unit and outputting a measurement value indicating a capacitance for the touchpad unit, the method comprising:
a calibration step of computing a sensor output value by calibrating, with a calibration coefficient, a measurement value output from the touch sensor circuit;
an updating step of updating the calibration coefficient when an update instruction is received from an external source, so that the sensor output value computed with the updated calibration coefficient in the calibration step becomes equal to a predetermined reference value;
a judging step of judging that
an operating member is in contact with the touchpad unit when a sensor output value computed before the

update of the calibration coefficient is greater than a contact-judgment threshold, and

the operating member is no longer in contact with the touchpad unit when a sensor output value falls below a noncontact-judgment threshold for a first time after the judgment that the operating member is in contact with the touchpad unit; and

a judgment threshold switching step of switching from the noncontact-judgment threshold to be used in a subsequent judgment in the judging step to a provisional noncontact-judgment threshold for a time period starting when the update takes place while the operating member is in contact with the touchpad unit and ending when the judgment that the operating member is no longer in contact with the touchpad unit is made in the judging step, and switching from the provisional noncontact-judgment threshold back to the noncontact-judgment threshold after the time period.

6. A non-transitory computer-readable storage medium having a control program for causing a computer to control a mobile terminal that includes a touch sensor circuit, the touch sensor circuit including a capacitive touchpad unit and outputting a measurement value indicating a capacitance for the touchpad unit, the program comprising code operable to cause the computer to perform:

a calibration step of computing a sensor output value by calibrating, with a calibration coefficient, a measurement value output from the touch sensor circuit;

an updating step of updating the calibration coefficient when an update instruction is received from an external source, so that the sensor output value computed with the updated calibration coefficient in the calibration step becomes equal to a predetermined reference value;

a judging step of judging that

an operating member is in contact with the touchpad unit when a sensor output value computed before the update of the calibration coefficient is greater than a contact-judgment threshold, and

the operating member is no longer in contact with the touchpad unit when a sensor output value falls below a noncontact-judgment threshold for a first time after the judgment that the operating member is in contact with the touchpad unit; and

a judgment threshold switching step of switching from the noncontact-judgment threshold to be used in a subsequent judgment in the judging step to a provisional noncontact-judgment threshold for a time period starting when the update takes place while the operating member is in contact with the touchpad unit and ending when the judgment that the operating member is no longer in contact with the touchpad unit is made in the judging step, and switching from the provisional noncontact-judgment threshold back to the noncontact-judgment threshold after the time period.

7. The mobile terminal according to claim **1**, wherein the judgment threshold switching unit calculates the provisional noncontact-judgment threshold based on the sensor output value.

8. The mobile terminal according to claim **7**, wherein calculating the provisional noncontact-judgment threshold comprises subtracting the sensor output value from the predetermined reference value.

9. The mobile terminal according to claim **1**, wherein the predetermined reference value is a center value of a range of possible sensor output values.

10. The mobile terminal according to claim **1**, wherein computing the sensor output value based on the measurement value comprises subtracting a calibration coefficient from the measurement value.

11. The mobile terminal according to claim **10**, wherein updating the sensor output value so as to be equal to the predetermined reference value comprises updating the calibration coefficient so that it is equal to a difference between the sensor output value and the predetermined reference value.

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